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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : E04C 2/34, B32B 3/24, 3/12

A1

(11) International Publication Number: WO 91/19866

(43) International Publication Date: 26 December 1991 (26.12.91)

(21) International Application Number: PCT/GB91/00981

(22) International Filing Date: 18 June 1991 (18.06.91)

(30) Priority data:
9013629.2 19 June 1990 (19.06.90) GB

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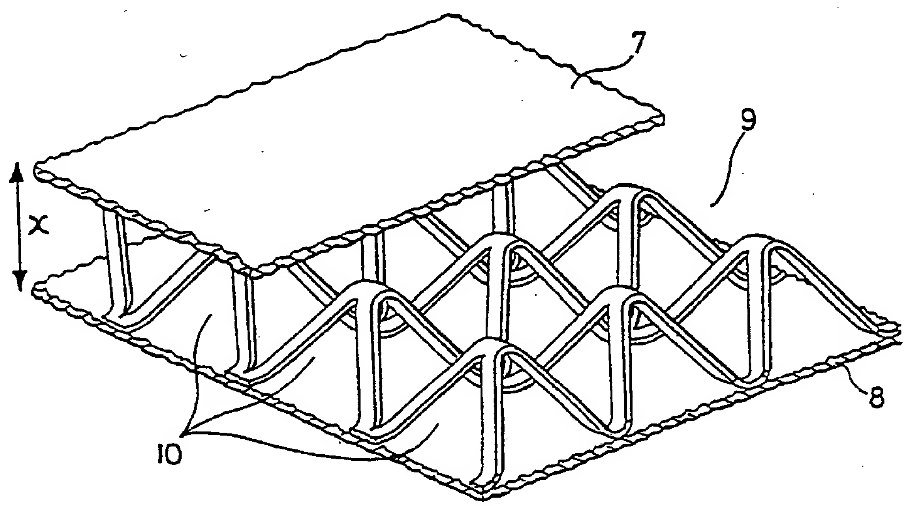
(81) Designated States: AT, AT (European patent), AU, BB, BE (European patent), BF (OAPI patent), BG, BJ (OAPI patent), BR, CA, CF (OAPI patent), CG (OAPI patent), CH, CH (European patent), CI (OAPI patent), CM (OAPI patent), DE, DE (European patent), DK, DK (European patent), ES, ES (European patent), FI, FR (European patent), GA (OAPI patent), GB, GB (European patent), GN (OAPI patent), GR (European patent), HU, IT (European patent), JP, KP, KR, LK, LU, LU (European patent), MC, MG, ML (OAPI patent), MR (OAPI patent), MW, NL, NL (European patent), NO, PL, RO, SD, SE, SE (European patent), SN (OAPI patent), SU, TD (OAPI patent), TG (OAPI patent), US.

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: COMPOSITE MATERIALS



(57) Abstract

The difficulty of producing composite materials in-profiled form is overcome by the provision of a composite material in which a relatively thick core layer (9) comprises a continuous array of open polyhedral frames (10), which frames are bonded at their outermost points to a relatively thin outer layer or layers (7, 8) of a durable, high strength material. The array of frames may be produced by distortion of a suitable expanded metal sheet comprising a two-dimensional network of polygons. The core layer is of relatively high strength and low weight, and can be performed into desired shapes, allowing for ease of production of profiled composite materials. The invention also provides a method of manufacture of such a material, and a structure and a composite panel formed from the material. The material is of use for purposes such as cladding, flooring and panelling, for instance in the building industry.

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Title: Composite Materials

Field of the invention

This invention relates to composite materials and to methods for their manufacture.

Background to the Invention

Composite materials, in one form or another, have been in use for centuries. From Phonecian bows, which were laminated from wood and animal hide, through the timber and wrought iron structures used in the 18th and 19th Centuries, to the reinforced concrete of the 20th Century, the principles are the same. These are to optimise the performance, weight and cost of a component or structure by the juxtaposition of materials of differing properties.

Composite panels represent one particular way in which composite materials can be manufactured and used. They typically consist of two relatively thin outer layers ("skins") of a durable, high strength material having a high elastic modulus, which skins are separated by a thicker "core" layer of a lower bulk performance material. This core layer must be able to transmit stresses throughout the panel, and must provide adequate support to the outer skins to allow them to resist applied loads.

Usually, the core material is of a low density, so that the resulting composite panel is not only high in strength but also of a relatively light weight.

In recent years, advanced performance composite panels have become available. These typically make use of aluminium sheeting or reinforced plastics materials for the outer skins, and an aluminium core which may be, for instance, a corrugated sheet or a honeycomb-like material. The resulting panel is lightweight but high in strength, and is of great use in the aerospace, marine, automotive and building industries for purposes such as cladding, flooring and panelling.

One limitation of such composite materials, however, is that they must generally be produced in flat sheet form. Any complex profile required in a structure to be produced from these materials must therefore be built up by a time-consuming process of cutting the flat sheets to the required shape and size and subsequently bonding the cut sheets together using a suitable adhesive. The disadvantages of this process result both from the added labour and cost involved and from risks associated with the loss of strength and integrity of the structure that is possible when jointing planar sheets of composite material. Futhermore, structures having large, smooth curves are very difficult to produce in this way.

It is therefore an aim of the present invention to provide a composite material, and a method for its manufacture, which overcomes or at least mitigates the disadvantages associated with currently available materials.

Statement of the Invention

According to the present invention there is provided a composite material comprising a relatively thin outer layer or layers of a durable, high strength material and a thicker core layer bonded to the outer layer or layers, characterised in that the core layer comprises a continuous array of open polyhedral frames, which frames are bonded at their outermost points to the outer layer or layers of the composite material.

The array may be formed from a two-dimensional "net" of polygons which has been distorted so as to produce a three-dimensional network of polyhedral frames. The net is conveniently an expanded metal sheet of the type commonly available, which may comprise a lattice network of squares, triangles, hexagons or any other tessellating polygons. Preferably, an expanded metal sheet comprising a lattice network of squares or rhombi is used, which on suitable distortion will produce a three-dimensional array of square-based pyramidal frames.

The polyhedral frames may be formed from lengths of wire, interconnected in such a way as to produce an array of such frames. The array may in this case be formed by the distortion of a two-dimensional sheet of wire mesh or netting in which the interconnected wires define an appropriate net shape.

The polyhedral frames are preferably square-based pyramidal frames. The frames are then bonded to the outer layer or layers of the composite material at their apexes.

Thus, use is made, in the core layer of the composite material of the present invention, of the well-known technique of utilising lattice beam arrangements to support applied forces.

The structure and use of lattice beam arrangements are well known. By separating the upper ("compression") and lower ("tension") faces of a supporting beam with welded, or pin jointed diagonal members, the beam structure is able to resolve imposed vertical loads as pure tension and compression forces within all members. The mass per unit run is then far lower than for an equivalent rolled or drawn section. Of course, the penalty when using a single plane beam is a lack of lateral stability. Crane jibs and structural members for some buildings are therefore sometimes produced as three integrated lattice beams forming the sides of a triangular prism. This has greatly improved lateral strength compared to the single plane structure.

The logical extension of this is the lattice roof, where loads across the entire horizontal plane of a roof panel are borne by diagonal lattice members radiating from the inner roof face. These lattice members are attached to horizontal "stringers" (which take the tension forces) lying in a horizontal plane beneath the roof plane itself. Such "layer grid structures" have been widely used in conference halls, theatres, exhibition centres, etc.

Whilst the structural advantages of such arrangements are well known and widely used in the larger-scale applications described above, their use in the field of composite materials has apparently never been appreciated. The present invention, however, makes use of the technique

on a much smaller scale, in order to produce a lightweight but high strength core layer for use in composite materials. As a result, the composite material of the present invention can be greater in strength, lighter in weight and lower in cost than currently available alternatives.

In addition, the lattice-type core layer of the composite material of the present invention is more suitable than conventional core materials for pre-forming into desired shapes. This allows for easier production of complex profiles in structures formed from the composite material. One or both of the outer layers could, for instance, be pre-formed to the desired shape, and the core layer easily deformed to match that shape.

Both the outer layer(s) and the core layer can be formed of any suitable material such as aluminium, steel (including galvanised or stainless steel), certain types of plastics materials or GRP (glass reinforced plastics) sheets. Conveniently, the core layer is formed from stainless steel preferably in the form of an expanded steel sheet. However, the core layer need not necessarily be made of metal; the use of a more malleable material would, for instance, allow the core layer to be easily moulded to a desired shape and hence enable a wide variety of different geometries to be explored.

Outer layers are preferably formed from materials having a high elastic modulus (Young's modulus of elasticity).

Outer layers may also have a decorative or functional finish applied to their outer surfaces, for example, vitreous enabel, decorative plastics, wood or stone veneer

paint or a protective coating of some form.

The thickness of the composite material and of the outer and core layers will depend on the materials of which the composite material is made, the intended use and the desired weight of the final product, among other considerations. Typically, the composite material is approximately 22mm thick, and the outer layers each approximately 1mm thick.

The core layer is conveniently bonded to the outer layers by means of a suitable adhesive. The adhesive may be applied as a coating on the inner surface of one of the outer layers, prior to contacting that outer layer with the core layer to which it is to be bonded. In this way, the effect of surface tension would be to form reinforced fillets at each node, ie. at each point of contact between the core layer and the outer layer. However, more preferably the adhesive is applied to the nodes of the core layer (for instance, by passing the core layer between rollers which apply the adhesive). Again, surface tension would cause the adhesive to remain at the nodes, however, the total weight and cost of the composite panel would be reduced by avoiding the need to apply adhesive to areas of the outer layers not in contact with the core layer.

The composite material of the present invention can be formed into structures of any desired shape and size. Accordingly, the present invention also provides a structure formed from the composite material of the invention, and a composite panel formed from the composite material of the invention.

The present invention also provides a method of manufacture of a composite material, comprising the steps of distorting a two-dimensional net of polygons so as to produce a three-dimensional continuous array of open polyhedral frames; and bonding the frames at their outermost points to an outer layer or layers of a durable, high strength material. In this way, a composite material is formed which comprises a core layer (the array of polyhedral frames) and an outer "skin" layer attached to it. The array may be bonded to two outer layers, one above and one below it, so as to form a "sandwich" composite material in which the core layer separates two outer layers.

The two-dimensional net is conveniently an expanded metal sheet, preferably comprising a lattice network of squares or rhombi. The net is then conveniently distorted by corrugation, such that the alternate "peak" and "trough" lines of the corrugations lie along the minor axes of the rhombi of the network.

The polyhedral frames of the array may be bonded to the outer layer or layers by applying a coating of a suitable adhesive to the inner surface of one of the outer layers, prior to contacting that outer layer with the core layer to which it is to be bonded. Alternatively, the adhesive coating may be applied to the outermost points of the core layer polyhedral frames, prior to contacting the core layer to the outer layer or layers to which it is to be bonded. Either or both of the outer layers may be pre-formed to a desired profile prior to the bonding step, as may the core layer.

The present invention will now be described by means of

the following examples and with reference to the accompanying drawings, of which:

Figures 1 to 3 show examples of known composite materials;

Figure 4 shows a composite material in accordance with the present invention;

Figure 5 shows a portion of the expanded metal sheet used in the manufacture of the material of Figure 4;

Figure 6 and 7 show further examples of expanded metal sheets of use in the manufacture of composite materials in accordance with the present invention; and

Figure 8 shows an alternative example of a composite material in accordance with the present invention.

Detailed Description of the Drawings

In Figure 1, a sample of a known composite material is shown in perspective view. The material comprises an inner core layer 1 and two outer "skin" layers 2 and 3. The upper layer 2 is shown cut away in part so as to reveal the nature of the core layer 1. This core layer has a honeycomb-like structure, comprising a close-packed array of hollow hexagonal cylinders 4. The core layer is formed of a lightweight metal such as aluminium and therefore has a fairly low density. The outer layers 2 and 3 are usually made of either aluminium or a reinforced (eg. by means of woven glass-fibres) plastics material.

The composite material shown in Figure 1 is generally

expensive and time-consuming to produce, due to the processes involved in manufacturing the honeycomb-like core layer.

Figures 2 and 3 show further examples of known composite materials, again in perspective view. Each comprises two outer layers 5, of aluminium or galvanised steel, and a core layer 6 of corrugated metal separating the two outer layers. The core layers of Figure 2 and 3 (shown schematically) illustrate different shapes of corrugation for the core layer.

The composite material, a sample of which is shown in perspective in Figure 4, has been manufactured in accordance with the present invention. The material comprises an upper layer 7 (shown partly cut away) and a lower layer 8, separated by the core layer 9. The core layer comprises a continuous array of open frames 10, each of which is square-based pyramidal in shape. The frames are bonded at each apex to the outer layers 7 and 8.

The core layer is formed from an expanded metal sheet 11, a portion of which is shown in Figure 5. This sheet comprises a two-dimensional "net" of rhombi. In order to produce the core layer 9 of the material shown in Figure 4, the sheet 11 is corrugated, such that the alternate "peak" and "trough" lines of the corrugations lie along the minor axes of the rhombi of sheet 11. In this way, a three-dimensional network of pyramidal frames is formed.

Expanded metal sheets such as that shown in Figure 5 are well known and widely available. They are produced by semi-shearing sheet metal, and are usually used as walkways, stair treads and the like. They are generally

available in a wide variety of different patterns, two further examples of which are shown in Figure 6 (network of hexagons) and Figure 7 (a more irregularly shaped network, based loosely on a hexagonal structure).

Many differently shaped networks of the general form shown in Figures 5 to 7 may be of use in the manufacture of composite materials in accordance with the present invention, so long as they can be corrugated or otherwise deformed to produce an array of open polyhedral frames having the desired strength and density. In particular, metal sheets based on a network of triangles or of hexagons are envisaged to be of use.

The upper and lower layers of the material shown in Figure 4 may be made of aluminium, GRP sheeting or a suitable laminate. They are 1 mm thick, the total material thickness (distance x) being 22 mm. They are bonded to the core layer 9 by applying a coating (of approximately 0.5 mm) of a suitable adhesive to the outermost points of the polyhedral frames of the core layer, and then contacting the core layer with the outer layers 7 and 8. This causes the formation of reinforced fillets at the apexes or nodes of the core layer, due to surface tension effects. Once both upper and lower layers have been bonded to the core layer, a composite material of considerable strength has been produced. The resultant material is also low in weight and can be manufactured at relatively low costs, especially since the core layer is so easily manufactured.

The process of bonding together the outer and core layers may be a continuous or semi-continuous automated process, whereby the three layers are brought together in

continuous lengths with the adhesive coatings already applied.

A variety of configurations of the composite material of the present invention are possible, depending on the ultimate properties of the final structure required. For example, for increased point impact resistance a thicker skin would be appropriate, whereas for greater core compressive strength both the core layer thickness and the included angle or polyhedral frame size/geometry may be appropriately selected. Similarly, as already noted, materials selected for the skins and for the core need not necessarily be the same and may be chosen to suit the application and the environment in which the final structure will be used.

As an example, Table 1 shows typical (projected) densities for various configurations of composite panel in accordance with the invention.

The outer layers 7 and 8 may of course have a decorative or functional finish applied to their outer surfaces, such as vitreous enamel, decorative plastics, wood or stone veneer or paint, to improve aesthetic appearance, or some form of protective coating.

An alternative type of composite material, also in accordance with the present invention, is illustrated in Figure 8. This material comprises an upper and a lower outer layer (12, 13) as in the material shown in Figure 4. However, in this case, the core layer 14 is formed from lengths of interconnected wire which together define an array of open pyramidal frames similar in structure and in function of those of Figure 4.

The principal advantage of composite materials such as those shown in Figures 4 and 8 is the ease with which they can be formed into structures having complex profiles. The core layers 9 and 14 are readily deformed into desired shapes and can be sandwiched between outer layers which have been pre-formed (eg. by conventional pressing techniques) to the desired profile to result in the required shape of composite structure.

Both outer layers may be pre-formed, adhesive applied to their inner surfaces, and then brought together with the core layer between them. In this case, the core layer will readily deform to produce the required moulded profile. Alternatively, the core layer and one of the outer layers may be preformed and bonded together, prior to application of the second outer layer.

The composite materials of Figures 4 and 8 can also be produced, if required, with only one outer skin bonded to the "core" layer.

Since neither the outer nor the core layers need be made of metal, the composite material of the invention may comprise a moulded core layer, thus allowing for even easier shaping of the material. This is in contrast to currently available composite materials which, as described above, require complex and time-consuming fabrication before the required profile can be built up from the flat sheets available.

It will be seen from the above that the present invention combines the advantages of currently known composite materials with the structural advantages achievable using

a lattice arrangement for the core layer.

Typical uses of the composite material provided by the invention may include the production of structural or semi-structural members in ships, aircraft, vehicles or buildings, or of cladding materials.

Table 1

Configuration	Thickness (mm) (typical range)	Mass (kg/m^2) Aluminium Core	Stainless Steel Core
0.55mm skin 0.5mm core @ 60° (included angle)	12 - 15	4.3	12.3
0.55mm skin 1mm core @ 60°	12 - 15	5.4	15.4
0.55mm skin 0.5mm core @ 30°	25 - 30	5.5	15.7
1.0mm skin 1.0mm core @ 60°	25 - 30	7.8	22.3
0.55 mm skin 1.0mm core @ 30°	50 - 60	7.6	21.7
1.0mm skin 1.45mm core @ 30°	50 - 60	12.5	35.7

* Mass per unit area is the total for the composite material, including outer layers, core layer (of either aluminium or stainless steel) and bonding adhesive.

Claims

1. A composite material comprising a relatively thin outer layer or layers of a durable, high strength material and a thicker core layer bonded to the outer layer or layers, characterised in that the core layer comprises a continuous array of open polyhedral frames, which frames are bonded at their outermost points to the outer layer or layers of the composite material.

2. A composite material according to claim 1, wherein the array is formed from a two-dimensional "net" of polygons which has been distorted so as to produce a three-dimensional network of polyhedral frames.

3. A composite material according to claim 2, wherein the net is an expanded metal sheet comprising a lattice network of tessellating polygons.

4. A composite material according to claim 3, wherein the expanded metal sheet comprises a lattice network of squares or rhombi, which on suitable distortion will produce a three-dimensional array of square-based pyramidal frames.

5. A composite material according to claim 1 or claim 2, wherein the polyhedral frames are formed from lengths of wire, interconnected in such a way as to produce the array of frames.

6. A composite material according to claim 5, wherein the

according to any one of claims 1-12.

15. A method of manufacture of a composite material, comprising the steps of distorting a two-dimensional net of polygons so as to produce a three-dimensional continuous array of open polyhedral frames; and bonding the frames at their outermost points to an outer layer or layers of a durable, high strength material.

16. A method according to claim 15, wherein the array of polyhedral frames is bonded to two outer layers, one above and one below it, so as to form a "sandwich" composite material in which the array separates two outer layers.

17. A method according to claim 15 or claim 16, wherein the two-dimensional net is an expanded metal sheet.

18. A method according to claim 17, wherein the expanded metal sheet comprises a lattice network of squares or rhombi.

19. A method according to any one of claims 15-18, wherein the net is distorted by corrugation.

20. A method according to any one of claims 15-19, wherein the polyhedral frames of the array are bonded to the outer layer or layers by applying a coating of a suitable adhesive to the inner surface of one of the outer layers, prior to contacting that outer layer with the array of frames to which it is bonded.

21. A method according to any one of claims 15-19, wherein the polyhedral frames of the array are bonded to the outer layer or layers by applying a coating of a

array is formed by the distortion of a two-dimensional sheet of wire mesh or netting in which the interconnected wires define an appropriate net shape.

7. A composite material according to any one of the preceding claims, wherein the polyhedral frames are square-based pyramidal frames bonded to the outer layer or layers of the composite material at their apexes.

8. A composite material according to any one of the preceding claims, wherein the core layer is formed from stainless steel.

9. A composite material according to any one of the preceding claims, wherein the outer layer or layers are formed from a material having a high elastic modulus (Young's modulus of elasticity).

10. A composite material according to any one of the preceding claims, wherein the composite material is approximately 22 mm thick.

11. A composite material according to any one of the preceding claims, wherein the outer layer or layers are each approximately 1 mm thick.

12. A composite material according to any one of the preceding claims, wherein the core layer is bonded to the outer layer or layers by means of an adhesive.

13. A structure formed from a composite material according to any one of the preceding claims.

14. A composite panel formed from a composite material

suitable adhesive to the outermost points of the polyhedral frames, prior to contacting the array of frames to the outer layer or layers to which it is to be bonded.

22. A method according to any one of claims 15-21, wherein either or both of the outer layers is pre-formed to a desired profile prior to the bonding step.

23. A method according to any one of claims 15-22, wherein the array of polyhedral frames is pre-formed to a desired profile prior to the bonding step.

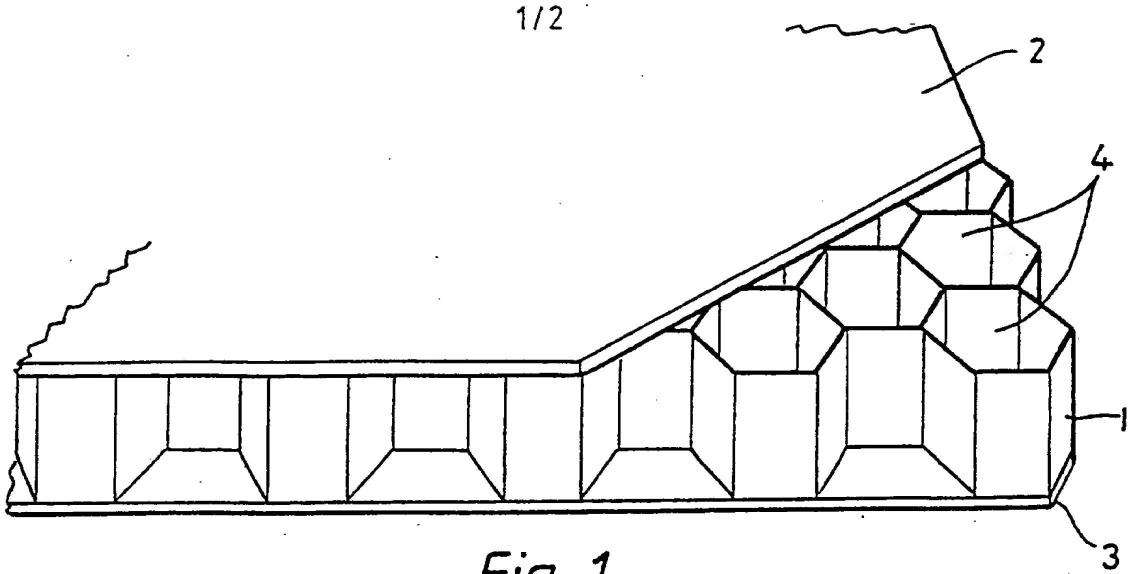

Fig. 1

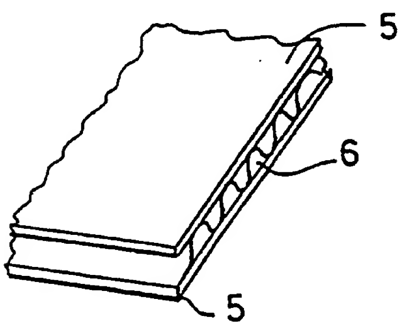

Fig. 2

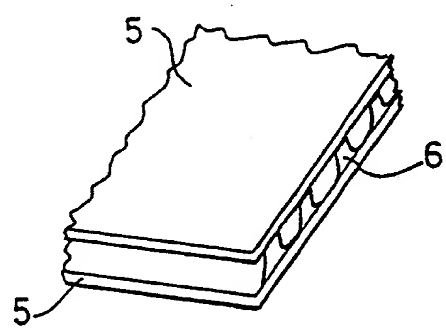

Fig. 3

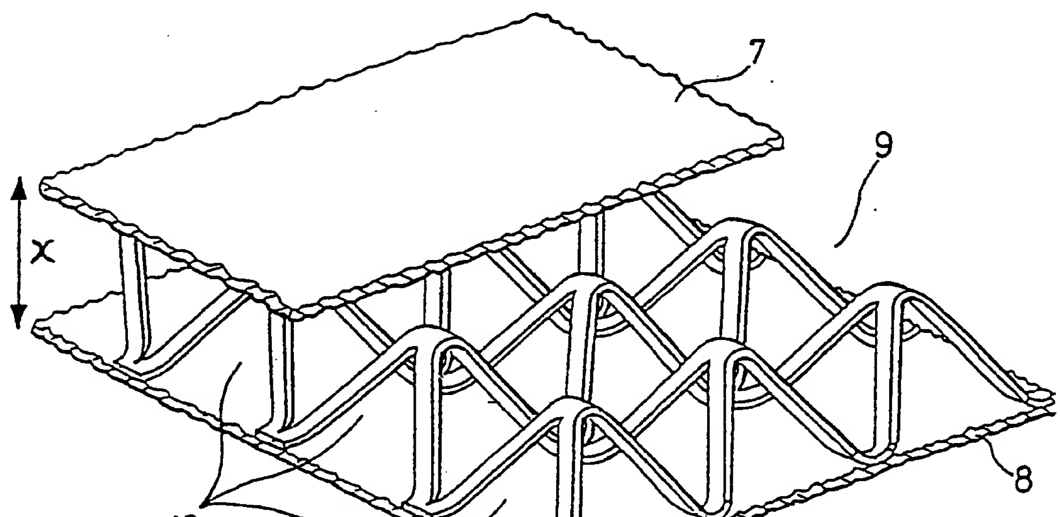

Fig. 4

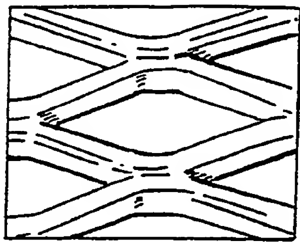

Fig. 5

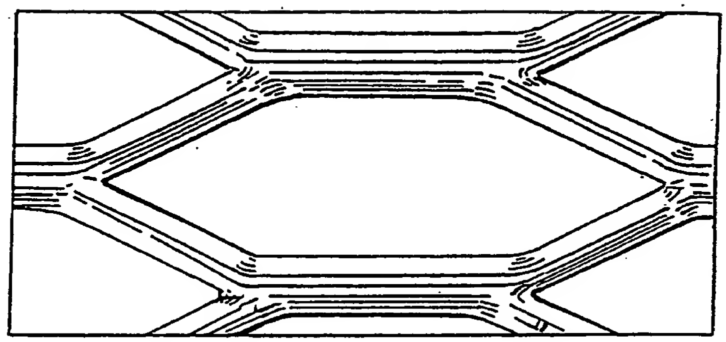

Fig. 6

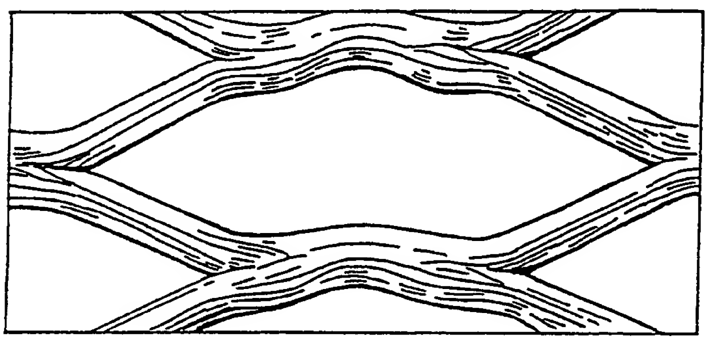

Fig. 7

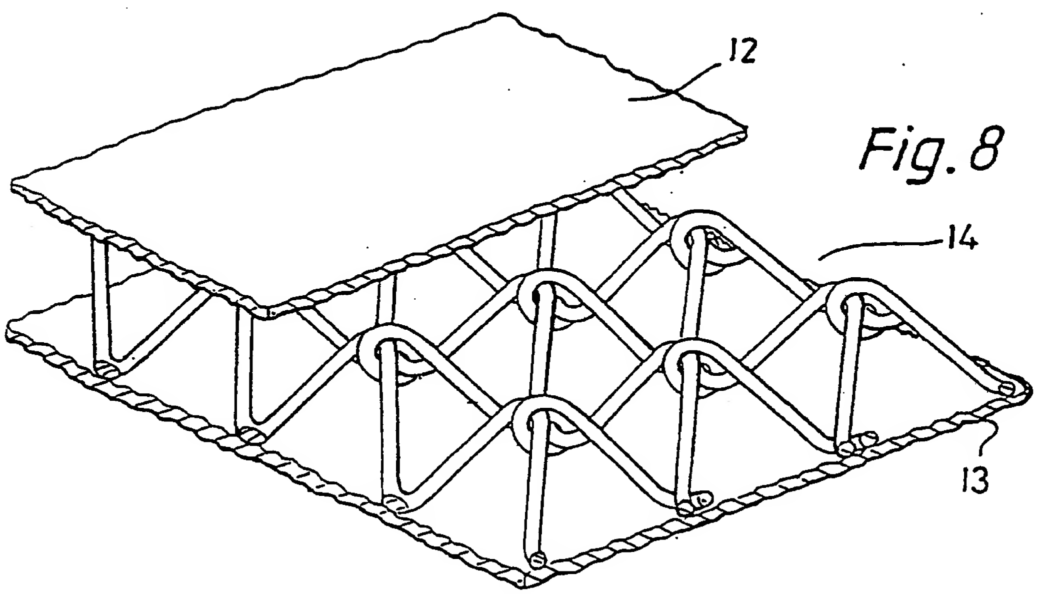

Fig. 8

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 91/00981

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 E04C2/34 ; B32B3/24 ; B32B3/12

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	E04C ; B32B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No.[13]
X	US,A,3 884 646 (KENNEY) May 20, 1975 see column 2, line 28 - line 36 see column 3, line 18 - column 4, line 48 see column 5, line 54 - column 6, line 21 see column 7, line 35 - column 8, line 22; figures	1-4,7-9, 12-20
A		5,6,10, 11,21-23
X	US,A,4 393 987 (ANDERSON ET AL.) July 19, 1983 see the whole document	1,2,4-7, 13-16,18
A		3,8-12, 17,19-23

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
17 SEPTEMBER 1991	16. 10. 91
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	IBARROLA TORRES O. Olga Ibarrola

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
X	FR,A,1 354 223 (CHAMMING'S JACK) January 27, 1964	1,2,4-7, 13-16, 18,19
	see the whole document	
A		3,8, 9-12,17, 20-23
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A	FR,A,1 365 579 (AKTIEBOLAGET KARLSTADS MEKANISKA WERKSTAD) May 25, 1964 see the whole document	1,12-15, 20,21

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A-3884646	20-05-75	None	
US-A-4393987	19-07-83	None	
FR-A-1354223		None	
US-A-3370393		None	
US-A-3258891		None	
DE-C-810187		None	
FR-A-1365579		None	

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